BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: 1975 Venus Lightside Flyby Trajectory of Spacecraft and Probes - Case 233

DATE: June 7, 1967

FROM: J. J. Schoch

ABSTRACT

Spacecraft and probe trajectories within Venus' sphere of influence were calculated for the 1975 Venus Lightside Flyby mission. The spacecraft trajectory is shown on Figure 1 and in more detail on Figures 2 and 3.

A spherical zone of about 30° in width can be reached with a probe within reasonable limits of entry angles as indicated in Figure 4. Figure 5 illustrates the ΔV penalty for having the probes arrive before or after the spacecraft reaches periapsis.

Having picked a convenient time of arrival for the probe, the anomaly of the entry point may be readily determined from Figures 6 and 7.

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MEMORANDUM FOR FILE

INTRODUCTION

Spacecraft and probe trajectories within the sphere of influence of the planet were calculated by utilizing the same computer program as used in a study of the 1975 Mars Flyby (Reference 1). The analysis is based on data for the 1975 Venus Lightside Flyby mission given in Reference 2.

SPACECRAFT TRAJECTORY

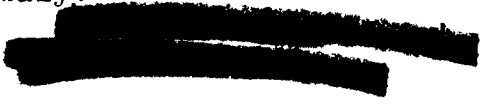
The nominal planetocentric spacecraft trajectory is based on the following data taken from Reference 2:

1. Planetary radius : R_v = 3,290 nautical miles
2. Periapsis radius : R_p = 3,559.78 nautical miles
3. Periapsis altitude : h_p = 269.78 nautical miles
4. Venus arrival speed: V_{oo} = 15,143.83 nautical miles.

From these, all other data relative to the spacecraft trajectory are determined such as:

1. Energy : 1.146677×10^8 ft^2/sec^2
2. Eccentricity : 1.43239 (-)
3. Semilatus rectum : 5.261175×10^7 ft
4. Velocity at periapsis: 35918.109 ft/sec
5. Angular momentum : 7.768956×10^{11} ft^2/sec.

The spacecraft trajectory within the sphere of influence of Venus is shown on Figure 1. This figure is drawn on scale and shows also the times to periapsis passage and the vehicle velocity relative to the planet. Figure 2 is a plot of Spacecraft Altitude and Time to periapsis passage vs. Anomaly from periapsis. Figure 3 shows Flight Path Angle and Velocity vs. Anomaly.



PROBE TRAJECTORIES

Probe trajectories were limited to entry angles of 10, 20, and 30 degrees at an altitude of 700,000 ft. above the surface. These two limits cover fairly well the whole range of possible entry angles; 10 degrees approaches the skip-out limit and the 30 degrees entry angle corresponds to decelerations of over 200g and excessive heating rates. The true anomaly with respect to the spacecraft hyperbola periapsis is shown in Figure 4. The entry points corresponding to 10, 20, and 30 degrees entry angle are shown as points A, B, and C on the lightside of the planet. Note that the figure is drawn to scale. The probe deployment distance was assumed to be 500,000 nautical miles, which on the scale of Figure 4 would represent about 21 feet. Of course, from that distance probes could be directed to the darkside of the planet. Points D, E, and F on Figure 4 were obtained with the supplementary entry angles 170, 160, and 150 degrees. The points A to F indicated on Figure 4 can be obtained with a very small injection ΔV about the order of magnitude of a midcourse correction. The probe enters the atmosphere at about the same time as the spacecraft reaches periapsis.

Figure 5 shows the ΔV penalty for having the probe enter the atmosphere either before or after spacecraft arrival at periapsis for various probe deployment distances ranging from 500,000n miles to 5,000,000n miles. Figures 6 and 7 show the ΔV expenditure required for reaching other anomalies. More specifically Figure 6 refers to the light side and Figure 7 to the darkside points. Both are applicable to the whole range of deployment distances between 500,000 and 5,000,000 miles.

Figure 6 shows that for a ΔV expenditure of 5,000 ft/sec, the anomaly may change over a range of 15 to 20 degrees. The points with close to zero ΔV on the curves of Figure 6 correspond to points A, B, C on Figure 4. These points are reached approximately at the time when the spacecraft passes periapsis. The left hand halves of the curves correspond to a later, the right hand halves to an earlier arrival.

Using values of entry angles between 10 and 30 degrees any desired value of anomaly within these limits may be reached.

In practice one would proceed approximately as follows:

A. Determine at what time the arrival of the probe is desired and pick the required ΔV value from Figure 5.

B. Determine for that value of ΔV the anomaly from Figure 6 and 7.

CONCLUSIONS

Within the entry angle limits of 10 to 30 degrees, probes will reach the planet within a 31 degree zone bounded by the parallel circles a and b in Figure 4. These are the only points on the planet that can be reached with a low ΔV. For a higher ΔV this zone can be extended somewhat. For instance, for a ΔV of 10,000 ft/sec, the zone is increased about 25 degrees on top and about 10 degrees on the bottom.

For line of sight communication, probes that reach the light side of the planet (points A, B, C on Figure 4) should be injected so as to enter the atmosphere slightly before (about 1/4 hour) the spacecraft's arrival at periapsis. For the same reason, probes to the darkside should enter the atmosphere about 1/2 hour after the spacecraft's arrival at periapsis.

JJ schoch

1013-JJS-amb J. J. Schoch

Attachments
References 1 and 2
Figures 1 - 7

REFERENCES

1. "1975 Mars Flyby Mission - Trajectories of Probes from Manned Spacecraft" - Case 103-2, by J. J. Schoch, dated July 6, 1966.

2. "1975 Venus Lightside Flyby Trajectory Surface - Case 103-2," by A. A. VanderVeen, dated December 28, 1966.

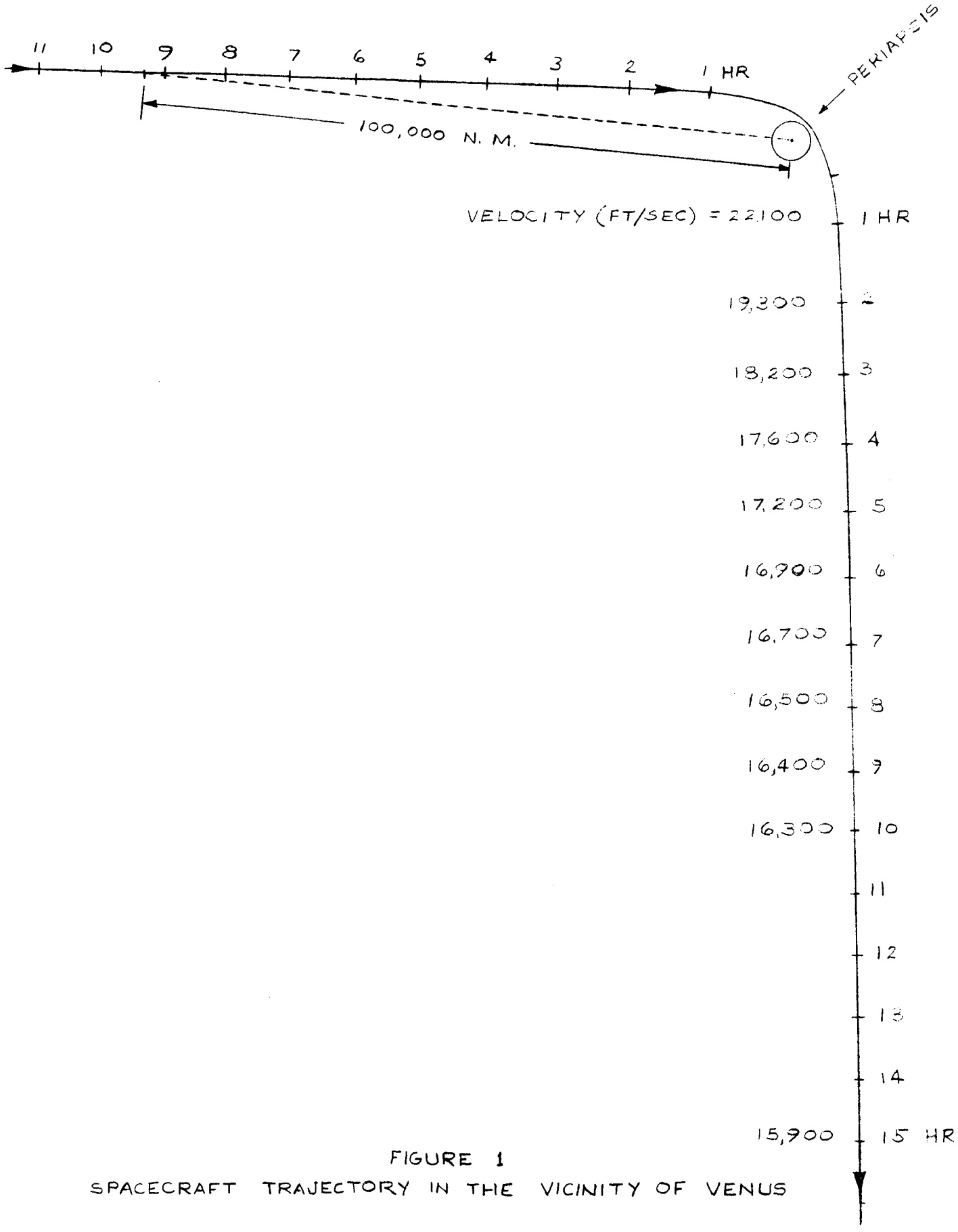


FIGURE 1

SPACECRAFT TRAJECTORY IN THE VICINITY OF VENUS

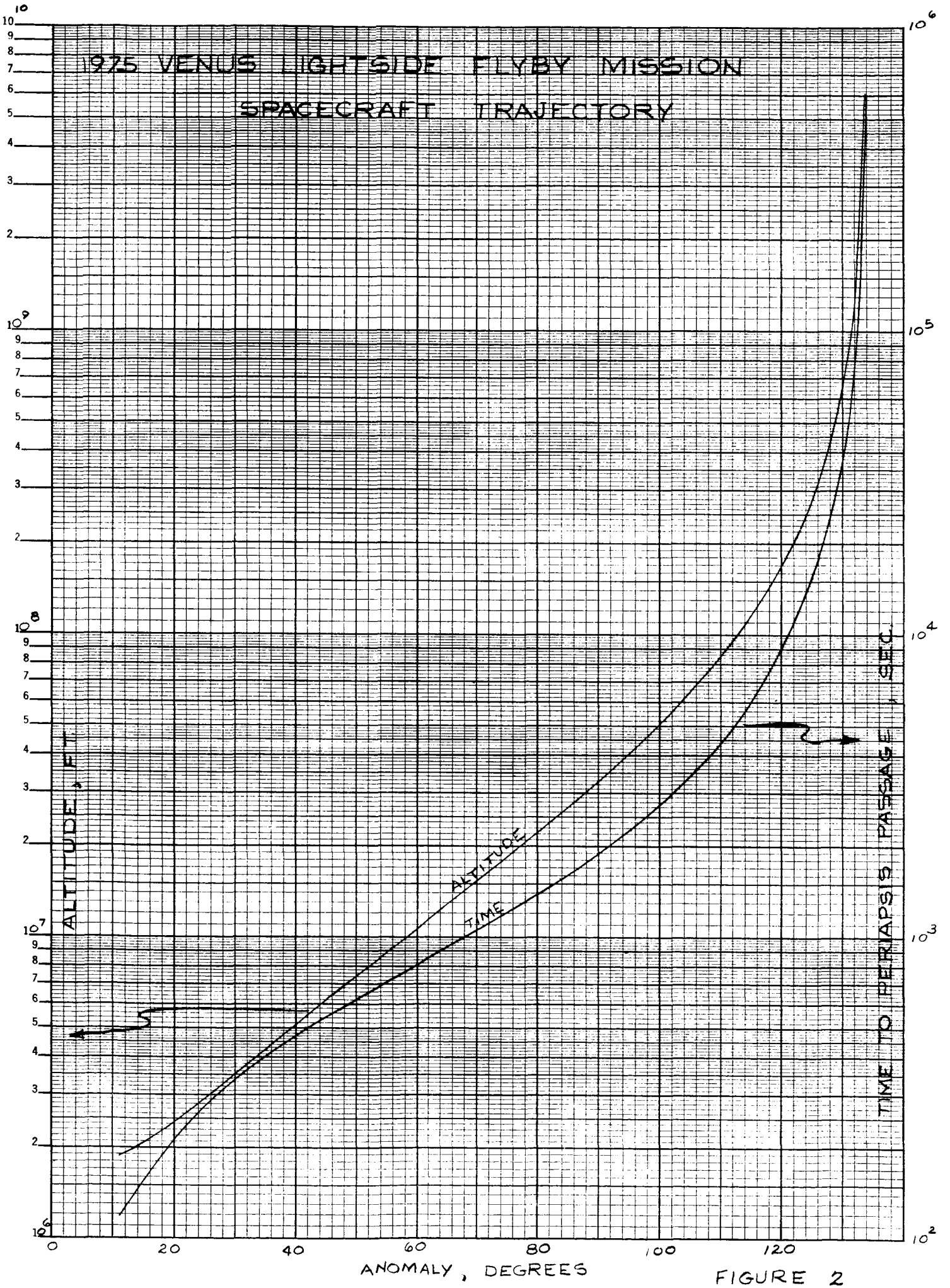
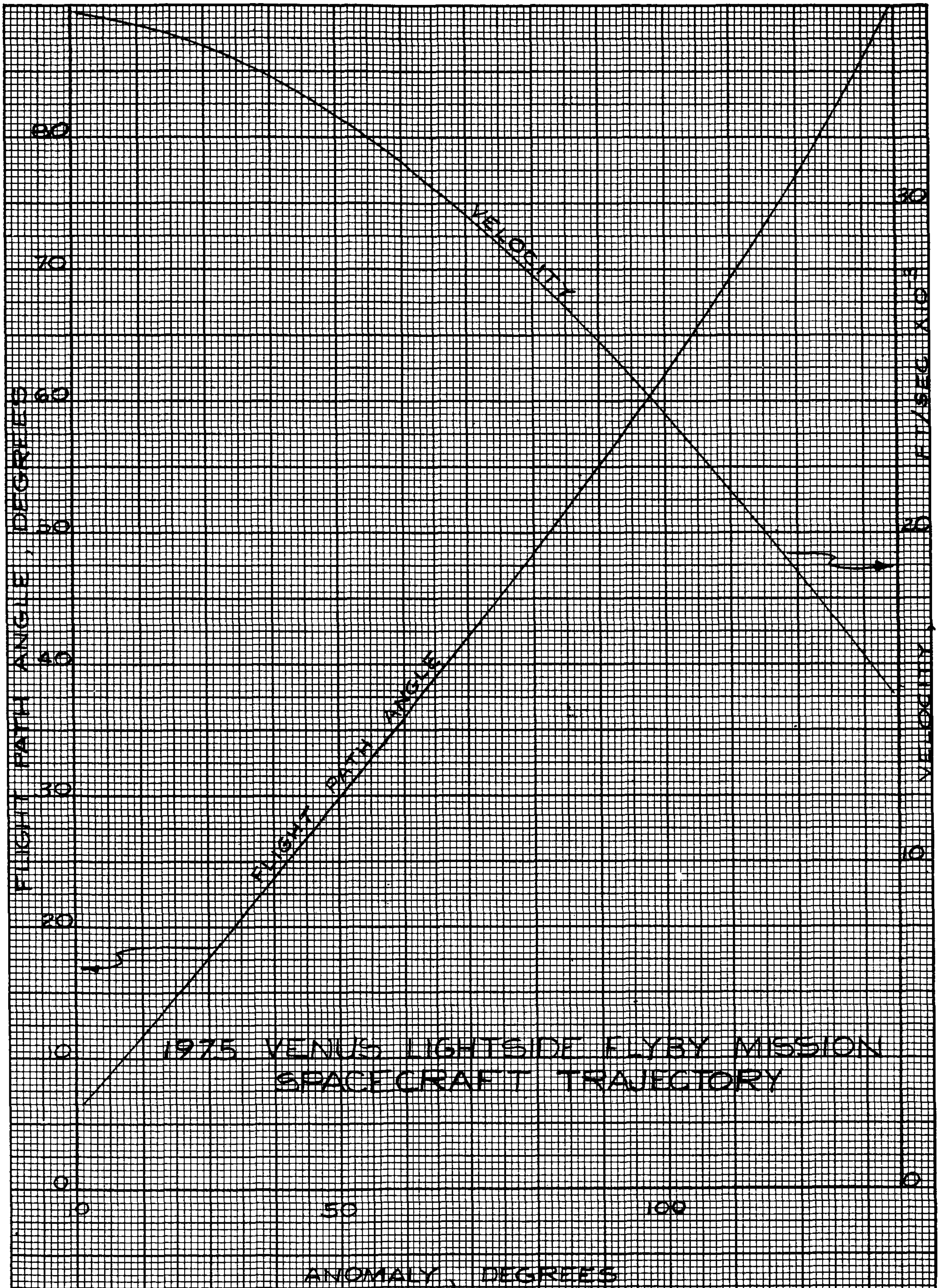

1975 VENUS LIGHTSIDE FLYBY MISSION
SPACECRAFT TRAJECTORY
ALTITUDE, FT
TIME TO PERIAPSIS PASSAGE, SEC
ALTITUDE
TIME
ANOMALY, DEGREES
0
20
40
60
80
100
120

FIGURE 2



1975 VENUS LIGHTSIDE FLYBY MISSION
SPACECRAFT TRAJECTORY
VELOCITY
FLIGHT PATH ANGLE
FLIGHT PATH ANGLE, DEGREES
VELOCITY, FT/SEC X 10^-3
ANOMALY, DEGREES
0
10
20
30
40
50
60
70
80
10
50
100

FIGURE 3

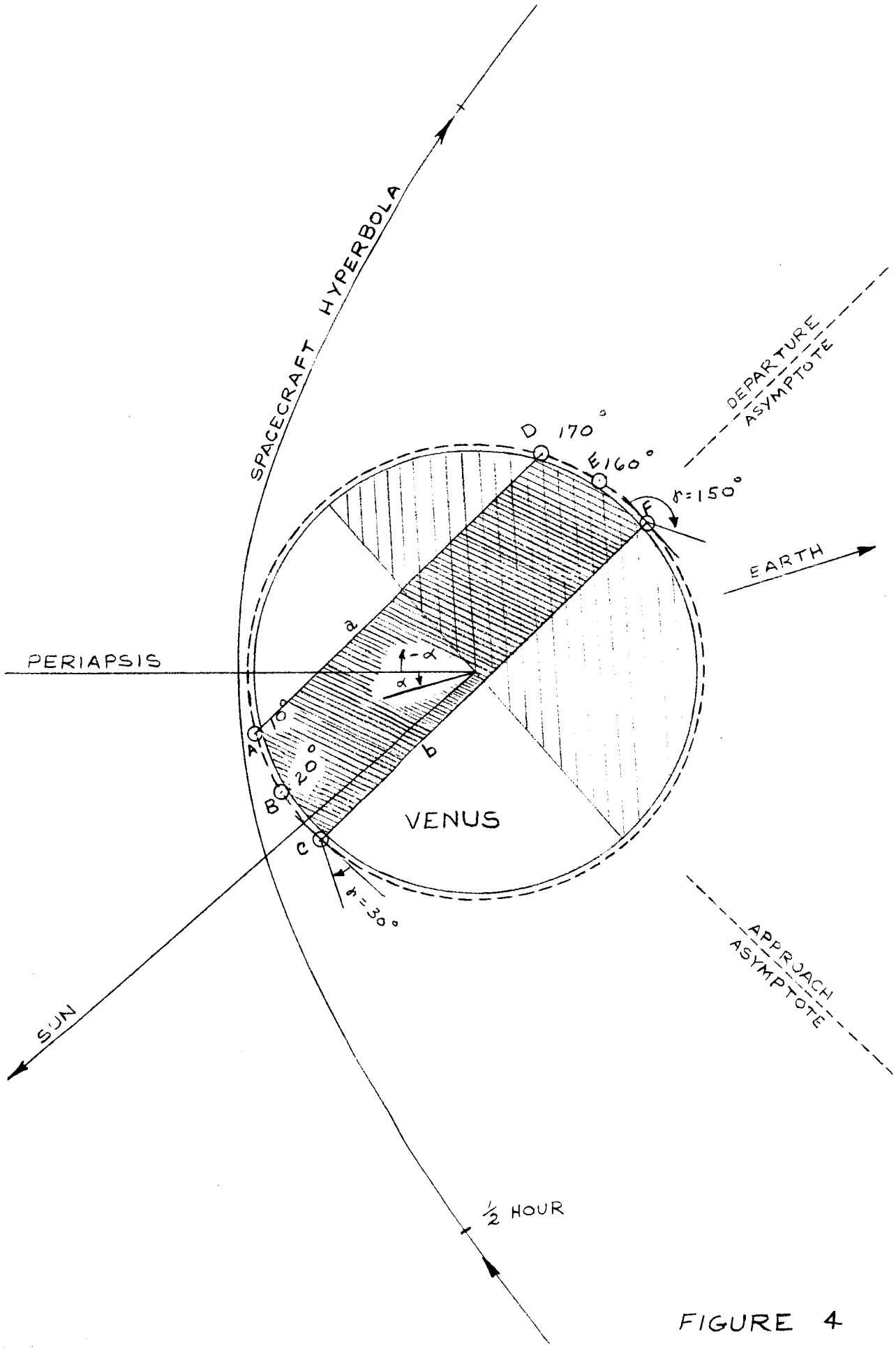

SPACECRAFT HYPERBOLA
DEPARTURE ASYMPTOTE
D 170°
E 160°
F
δ = 150°
EARTH
PERIAPSIS
a
f - α
α
A
10°
B
20°
C
b
VENUS
δ = 30°
SUN
APPROACH ASYMPTOTE
½ HOUR

FIGURE 4

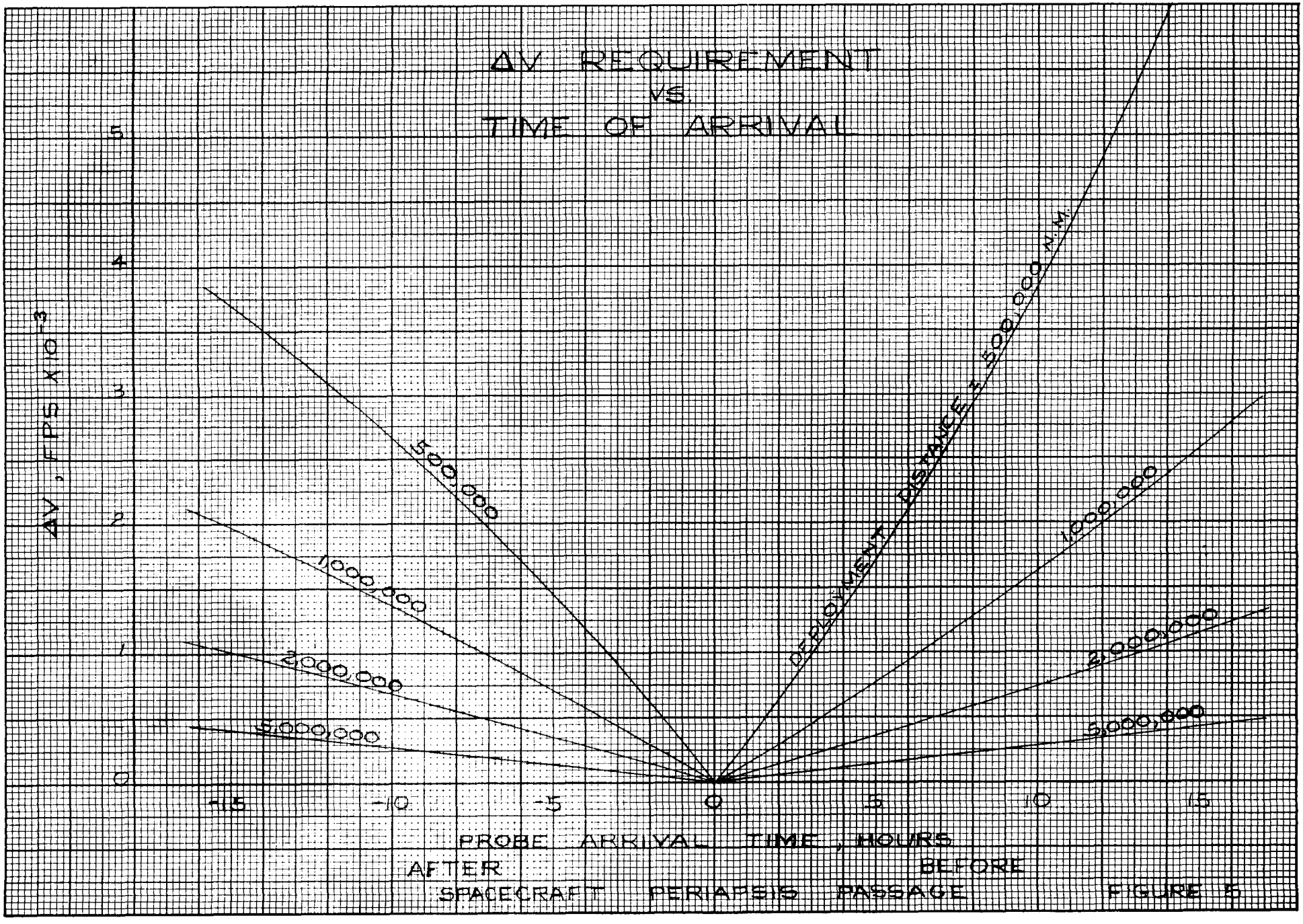

ΔV REQUIREMENT
VS.
TIME OF ARRIVAL
ΔV, FPS X 10⁻³
0
1
2
3
4
5
-15
-10
-5
0
5
10
15
PROBE ARRIVAL TIME, HOURS
AFTER SPACECRAFT PERIAPSIS PASSAGE
BEFORE
DISTANCE AT PERIAPSIS
500,000 N.M.
1000,000
2000,000
5000,000
500,000
1000,000
2000,000
5,000,000

FIGURE 5

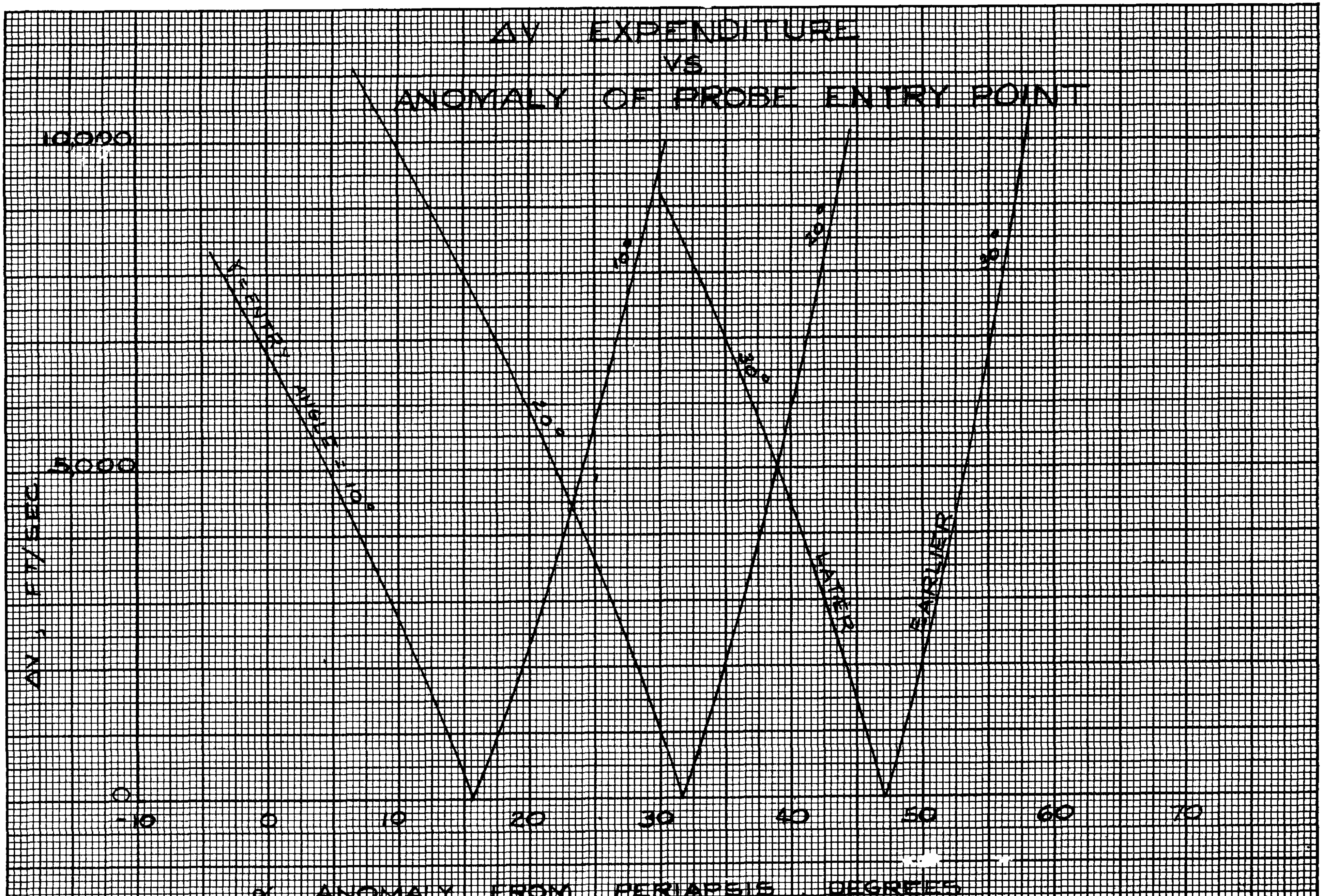

ΔV EXPENDITURE
VS
ANOMALY OF PROBE ENTRY POINT
10,000
5,000
0
ΔV, FT/SEC
-10
0
10
20
30
40
50
60
70
α, ANOMALY FROM PERIAPSIS, DEGREES
γ = ENTRY ANGLE = 10°
20°
30°
10°
LATER
EARLIER

FIGURE 6

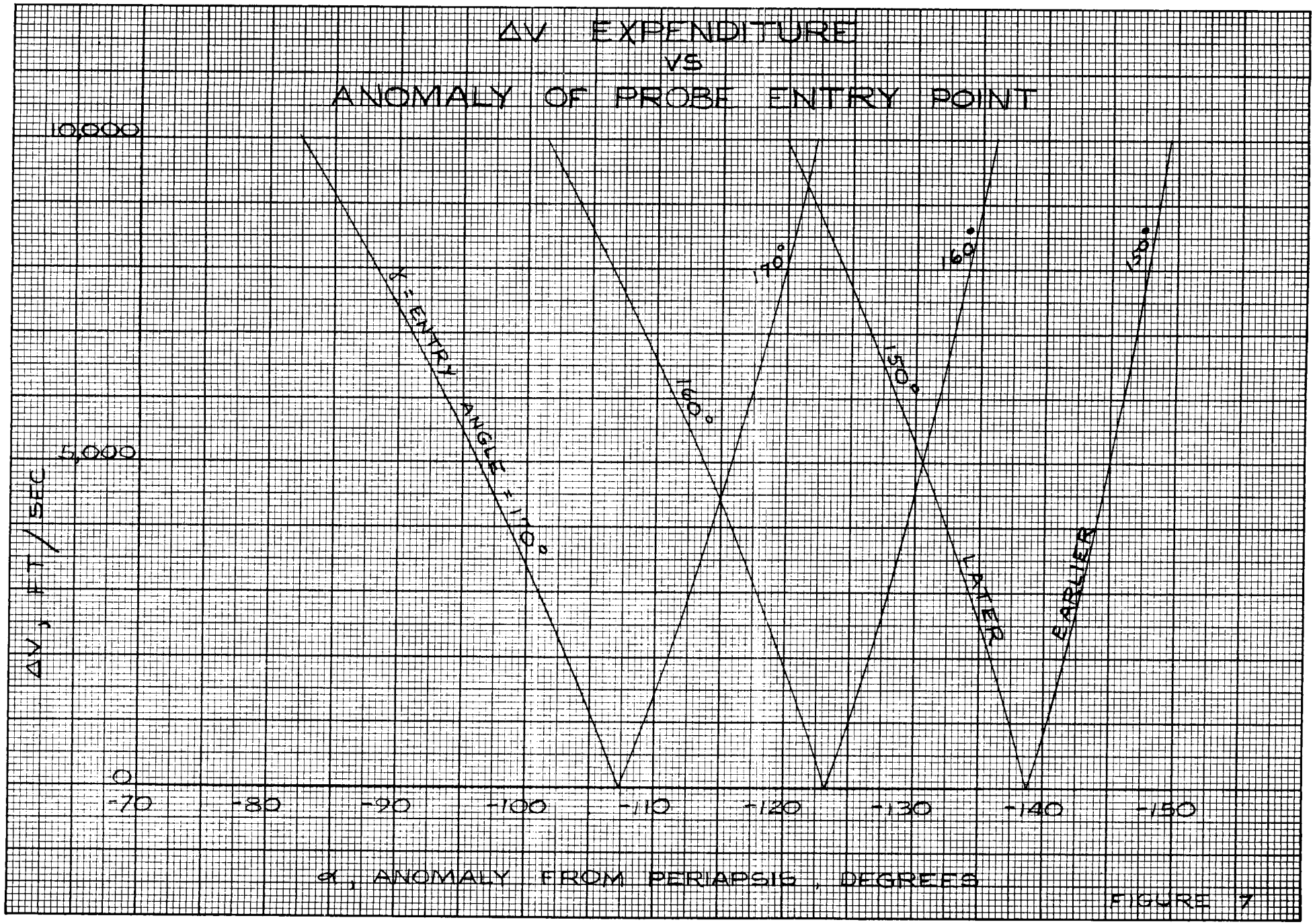

ΔV EXPENDITURE
VS
ANOMALY OF PROBE ENTRY POINT
10,000
5,000
0
ΔV, FT/SEC
-70
-80
-90
-100
-110
-120
-130
-140
-150
α, ANOMALY FROM PERIAPSIS, DEGREES
α = ENTRY ANGLE = -110°
-150°
-140°
-160°
-150°
LATER
EARLIER

FIGURE 7